Learned All Electrolytes
Vasopressors Antihypertensives

https://www.uptodate.com/contents/use-of-vasopressors-and-inotropes

Vasopressors			- hypertension tissue necrosis, acute renal failure - ischemia: cardiac, mesenteric, decreased peripheral perfusion
epinephrine	[β1 = β2 > α1* = α2*]	*At high plasma concentrations, α = β selectivity	tachycardia, hyperglycemia
norepinephrine	[β1 = α1 > β2 = α2]		tachycardia, hyperglycemia
phenylephrine			
dopamine	[β1 = β2 > α1*]	beta-agonist effect is gonna be maximized before the alpha-agonist effect can take place	tachycardia, hyperglycemia; decreased peristalsis arrhythmias (DA >> E/NE > PE/VP)
vasopressin			
angiotensin II			hypernatremia, hypokalemia, thrombosis
Inotropes	If you fix SV with inotropes, the HR will come down		
dobutamine	β1 β2 α1 agonist [β1 > β2 > α1] Onset <10min *HL 2-3min* 2-10 mcg/kg/min (max 20) metab: plasma clearance	HR ↑ MAP - PCWP↓ CO↑ SVR -/↓ Net effect is cardiac stimulation with modest vasodilation	tachyarrhythmia, hypotension, eosinophilia (rare)	consider: concomitant BB may limit effect
milrinone	$PDE_{3/4}$ inhibitor Onset 5-15min *HL 1-3hrs* 0.2-0.5 mcg/kg/min (max 0.75) metab: renal clearance	HR -/↑ MAP -/↓ PCWP↓ CO↑ SVR ↓	tachyarrhythmia, hypotension, thrombocytopenia (rare)	consider: delayed onset, prolonged HL in renal dysf
IV Vasodilators				
nitroglycerin	venous: ↓preload=↓pulm congestion HL 2-3min Use: acute relief of symptoms (dyspnea)	CVP↓↓ SVR -/↓ CO -/↑ PCWP↓ higher for SVR fx 5-10 mcg/min, titrated 5-10 q5-10min to effect (range: 10-200)	HA, hypotension	consider: tolerance (need for dose escalation); niche use in patients with concern for ischemia
nitroprusside	mixed: ↓preload=↓pulm cong; ↓afterload=↑CO HL 1-3min Use: optimization of CO/CI, relief of sx; eval of pulmonary HTN	CVP↓ SVR ↓↓ CO ↑ PCWP↓ 0.3-3mcg/kg/min	cyanide/thiocyanate toxicity may limit duration of use (esp hepatic/renal impairment), hypotension	consider: cost

Norepinephrine Equivalent

Vasopressor	Dose	Norepinephrine Equivalent
Norepinephrine	0.1 mcg/kg/min	0.1 mcg/kg/min
Epinephrine	0.1 mcg/kg/min	0.1 mcg/kg/min
Vasopressin	0.04 unit/min	0.1 mcg/kg/min
Phenylephrine	1 mcg/kg/min	0.1 mcg/kg/min
Dopamine	15 mcg/kg/min	0.1 mcg/kg/min

α1	↑SVR ↑MAP	blood vessels	vasoconstriction glycogenolysis, gluconeogen
α2	α2a ↓SVR ↓HR α2b ↑SVR ↓HR	presyn neuron smooth muscle	negative feedback constriction inhibits insulin release, induce glucagon
β1	↑CO ↑HR	heart blood vessels	chronotropy/inotropy vasodilation
β2	↓SVR	lungs blood vessels	bronchodilation vasodilation
D1 D2	↓SVR	kidney blood vessels	↑UOP vasodilation
vasopressin	↑SVR	blood vessels	vasoconstrict, Na-H2O retention, ↑cortisol
angiotensin II	↑SVR	blood vessels	vasoconstrict, aldosterone release

epinephrine 0.005-0.02 mcg/kg/min >0.05 mcg/kg/min	mixed α β more β1 β2 more α1 α2	 ↑chronotropy/inotropy vasoconstriction
norepinephrine	α1 α2 primarily (some β1 β2)	vasoconstriction ↑chronotropy/inotropy
phenylephrine	α1 α2	vasoconstriction
vasopressin	vasopressin	vasoconstriction
dopamine 1-5 mcg/kg/min 5-10 mcg/kg/min 10-20 mcg/kg/min	 D1 D2 β1 β2 α1 α2	 ↑UOP ↑chrono/ino ↓SVR vasoconstriction
angiotensin II	angiotensin II	vasoconstriction ↑Na ↓K, thrombosis

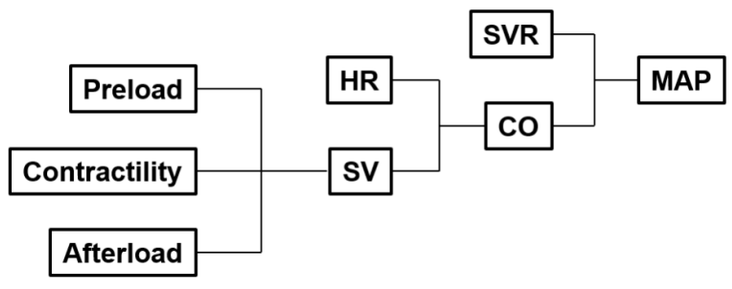
Vasopressors						
	DA	**α1**	**β1**	**β2**	**Other**	
dopamine*	+++++	+++	++++	++		2.5-20 mcg/kg/min
epinephrine*		++++	++++	+++		0.02-1 mcg/kg/min
norepinephrine*		+++++	+++	++		0.02-3.3 mcg/kg/min
phenylephrine		+++++				0.5-9 mcg/kg/min
vasopressin					V1 V2 agonism	0.01-0.04 units/min
angiotensin II					ATII agonism	5-30 ng/kg/min^
Inotropes						
dobutamine		+	++++	++		2.5-20 mcg/kg/min
milrinone					$PDE_{3/4}$ inhibitor	0.25-0.75 mcg/kg/min

*higher doses more α1 activity ^dose (up to 80 for 3h); lower if ACEi, won't work ARB
DA vasodilation (renal) **α1** vasoconstriction **β1** chronotropy/inotropy **β2** vasodilation

Low SVR can be seen with Sepsis, Anaphylaxis, Spinal shock, Adrenal Insufficiency, Hyperthermia, AV fistula, Vasodilator use
High SVR can be seen with Hypovolemia, Cardiogenic Shock, Hypothermia, Vasopressor use
Increased PVR can be seen with hypoxia, hypercapnea, increased sympathetic tone, polycythemia, precapillary pulmonary edema, pulmonary emboli, or lung compression (pleural effusion) and in ventilated patients.
Decreased PVR can be seen with oxygen, adenosine, isoproterenol, alpha-antagonists, inhaled nitric oxide, prostacyclin infusions, and high dose calcium channel blockers.

MAP	Mean Arterial Pressure (mean BP) MAP = (1/3 SBP) + (2/3 DBP)	70-10 mmHg
SV	Stroke Volume (from LV per beat) SV = CO/HR (mL/beat)	60-130
SI	Stroke Volume Index (mL/m^2/beat)	30-65
CO	Cardiac Output CO = SV*HR	4-8 L/min
CI	Cardiac Index CI = CO/BSA	2.8-4.2 $L/min/m^2$
CVP	Central Venous Pressure (Preload R)	2-8 mmHg
PCWP	Pulmonary Capillary Wedge Pressure (Preload L)	6-12 mmHg
RAP	Right Arterial Pressure	2-6 mmHg
RVP	Right Ventricle Pressure	15-25 mmHg
PAP	Pulmonary Artery Pressure	10-22 mmHg
SVR	Systemic Vascular Resistance (Afterload L, pressure LV has to pump against) SVR = 80*(MAP-CVP)/CO SVR ≅ MAP/CO	900-1400 $dyn*s/cm^5$
PVR	Pulmonary Vascular Resistance (Afterload R, pressure RV has to pump against) PVR = 80*(mPAP-PCWP)/CO	150-250 $dyn*s/cm^5$
PaO_2	partial pressure O_2	90 mmHg
SaO_2	arterial oxygen saturation	98%
pCO_2	partial pressure CO_2	40 mmHg (arterial)
$ScVO_2$	mixed venous oxygen saturation	60%–80%
$ScvO_2$	central venous oxygen saturation	

MAP = CO*SVR product of cardiac output and systemic vascular resistance
SVR afterload L, pressure LV has to pump against
CO = HR*SV product of HR and volume ejected by the heart
HR (chronotropy)
SV is impacted by preload, contractility, afterload
Preload volume in ventricles at end of diastole prior to systole; an increase in preload = increase contractility (except HF)
CVP preload right side volume status; PCWP preload left side volume status
Contractility (inotropy) ↑inotropy via ↑sympathetic activation, ↑catecholamines, ↑parasymp (vagal) inhibition, ↑afterload, ↑HR
Afterload resistance LV has to overcome to eject blood volume into aorta; controlled by vasoconstriction/vasodilation



hydralazine: afterload; vasodilation arterioles, little on veins; decreased systemic resistance
isdn: preload; vasodilation peripheral veins more so than arteries; reduces cardiac oxygen demand by decreasing preload (LV end-diastolic pressure); may modestly reduce afterload

Noninvasive Hemodynamic Monitoring: Mental status Urine output BP HR RR Pulse oximetry Capillary refill Skin temperature Skin color Skin turgor Transthoracic echocardiogram (TTE)
Invasive Hemodynamic Monitoring: Serum lactate Transesophageal echocardiogram (TEE) Arterial line Central venous catheter Pulmonary artery (PA) catheter (Swanz-Ganz catheter)

Hypovolemic Shock
↓preload, invasive monitoring CVP/PCWP
Hemorrhagic: volume loss secondary to blood loss (trauma, GI, surgery, anticoag)
Nonhemorrhagic: intravascular volume depletion (burns, dehydration, pancreatitis)
Management: source, fluid crystalloids, PRBCs, vasopressors MAP ≥60

Distributive (Vasodilatory) Shock
↓afterload (SVR)
1. Septic:
goal UOP >0.5, MAP >65, CVP 8-12
fluid resuscitation 30ml/kg crystalloids; vasopressors MAP >65 (norepi, epi)
empiric antimicrobial +/- antifungal/viral
2. Anaphylactic
epi 0.3-0.5 IV/IM stat
fluid resuscitation; vasopressor/epi MAP >65
supportive care (DPH/famot, steroids, albuterol)
3. Neurogenic
fluid resuscitation; vasopressors if refractory MAP 85-90
atropines sx brady

Cardiogenic Shock
↓CO (HR/contractility); hypofusion d/t cardiac failure (cold, wet/dry)
Monitor invasive (PCWP CVP CO ScVO2), noninvasive (hypo, ECHO, fluid/edema)
Management: early definitive restoration of coronary blood flow
cold/wet: inotrope+diuretic cold/dry: inotrope
when inotropes fail: epi/norepi, mechanical

Obstructive Shock
extra-cardiac obstruction
PCWP↑impaired diastolic fill; PCWP↓impaired systolic contraction
Monitor: invasive not required
Management:
cardiac tamponade (pericardiocentesis, drainage)
tension pneumo (fine needle decomp)
PE (heparin +/- thrombolysis/embolectomy)

↓ Low Values	Hemodynamic Parameter	↑High Values
volume expansion	CVP/PCWP—preload	diuresis or venodilators
vasopressors	SVR/PVR—afterload	arteriovasodilators
positive inotropes	CO/CI—inotropy/contractility	negative inotropes
positive chronotropes	HR—chronotropy	negative chronotropes

	MAP	CVP	PCWP	CO	SVR
Hypovolemic	↓	↓	↓	↓	↑
Distributive	↓	↓	↓	↑↓	↓
Cardiogenic	↓	↑	↑	↓	↑
Obstructive	↓	↑	#	↓	↑

Distributive=Vasodilatory; preload = CVP PCWP, afterload = SVR

FASTHUG – **F**eeding, **A**nalgesia, **S**edation, **T**hromboembolic Prevention, **H**ead of Bed Elevation, Stress **U**lcer Prophylaxis, **G**lucose Control

Sepsis
Fluid Resuscitation
IV fluid resuscitation is initiated to stabilize sepsis-induced tissue hypoperfusion
- at least 30ml/kg IV crystalloid fluid in first 3 hours
- target MAP 65
- resuscitated with goal of normalizing lactate
- avoid hydroxyethyl starches

Consider the 5 D's of fluids (drug, dose, duration, de-escalation, drug)
and ROSE 4 phases of therapy: ROSE (sine wave):
1. resuscitation (minutes) [net-positive]: 1st hit: shock; early goal-directed fluid management; early administration of fluid boluses
2. optimization (hours) [net-neutral]: 2nd hit: ischemia + reperfusion; organ rescue, guided fluid boluses
3. stabilization (days) [net negative-neutral]: 2nd hit: cont'd; organ support, late conservative fluid management
4. evacuation (weeks) [net negative]: 3rd hit: global increased permeability syndrome; late goal-directed fluid removal

	MAP	CVP	PCWP	CO	SVR	
Hypovolemic	↓	↓	↓	↓	↑	Preload, Contractility, Afterload → HR, SV → CO → SVR → MAP
Distributive	↓	↓	↓	↑↓	↓	Preload, Contractility, Afterload → HR, SV → CO → SVR → MAP
Cardiogenic	↓	↑	↑	↓	↑	Preload, Contractility, Afterload → HR, SV → CO → SVR → MAP
Obstructive	↓	↑	#	↓	↑	OR Preload, Contractility, Afterload → HR, SV → CO → SVR → MAP

Sepsis
qSOFA Criteria (≥2 criteria greater risk of poor outcomes, only valid ED/floor, not ICU): **SBP** <100 mmHg, **RR** >22, **AMS** mental status
SIRS Criteria (≥2 criteria for SIRS dx): **Temp** >38°C or <36°C, **HR** >90 bpm, **RR** >20, **WBC** >12k or <4K or >10% immature bands
sepsis: life-threatening organ dysfunction caused by a dysregulated host response to infection
[known/suspected infection + qSOFA ≥2 or change in SOFA ≥2]
septic shock: a subset of sepsis in which underlying circulatory and cellular/metabolic abnormalities are profound enough to substantially increase mortality
[sepsis + hypotension requiring vasopressors or lactate >2]

Tx:
fluid resuscitation: 30ml/kg IV bolus crystalloid fluid (NS, Lactated Ringers, plasmalyte) in first 6hrs
antimicrobials after culture (but don't delay)
vasopressors if hypotension refractory to IV fluids—norepi first-line, phenylephrine if tachy; can add another like epi, vasopressin if tachy
steroids: hydrocortisone 50mg IV q6h

Pain
causes: endotracheal tube, vascular access, procedures, underlying illness/injury, rolling/moving patient, immobile
consequences: suffering, increased stress response, chronic pain, PTSD< impaired wound healing

Numerical Pain Scale gold std Behavioral Pain Scale (**BPS**): goal 0 to 3 **CPOT**, in ICU: goal 0 to 2
Tx: opioids mainstay therapy: SE resp depression, decreased gastric motility, sedation, hypotension, GI upset
multimodal agents: APAP, epidurals, gabapentin, lidocaine, NSAIDs, ketamine
analgosedation: analgesia-based sedation regimen (pain treated first)
- allows intermittent dosing (preferred over CI to allow for drug clearance, prevention of accumu/over sedation)

oxycodone 3-6 hrs	continuous: n/a intermittent: 5-15 mg PO q4-6h	IR tablets can be crushed and put down NGT good enteral option
fentanyl 15-30 min	continuous: 50-200 mcg/hr intermittent: 25-100 mcg IVP q15-60min	accumulation in hepatic impairment, chest wall rigidity can use in true morphine allergy; tachyphylaxis occurs 200
hydromorphone 2-3 hrs	continuous: 0.2-2 mg/hr intermittent: 0.2-1 mg IVP q1-2h; 2-4mg PO q4-6h	accumulation in renal and hepatic impairment therapeutic option in morphine/fentanyl tolerance
morphine 3-5 hrs	continuous: 2-10 mg/hr intermittent: 2-4 mg IVP q1-2h; 10-20 mg PO q4-6h	accumulation renal impairment (typically not used in ICU) **histamine** release results in incr **hypotension**, itchiness, rash

APAP	PO: 325-1000 mg q4-6h IV: 650-1000 mg q4-6h	max 4000 mg/day reduce dose in hepatic impairment and elderly ≥65yo
gabapentin	PO: 100-300 mg TID, then 300-1200 mg TID	renal dose adjust SE drowsiness, dizziness, altered mental status
ketamine	bolus: 0.1-0.5 mg/kg infusion: 0.05-0.4 mg/kg/hr	hallucinations, hypertension analgesic + sedative
NSAIDs	ibuprofen: 200-800 mg PO q3-6h (2400 mg/d) ketorolac: 15-30 mg IV q6h (max 5 days)	avoid renal impairment and GI bleed contraindicated post-CABG

Agitation
causes: pain, lines/tubes, delirium, hypoxemia, sleep disturbances, withdrawal
consequences: increased cost, anxiety/PTSD, ventilator dyssynchrony, delirium, dislodging lines, harm

light sedation = RASS -2 to +1 critically ill, mechanically ventilated patients (+4 combative -5 unarousable)
deep sedation = RASS -4 to -5 ventilator dyssynchrony, NMBA paralytics, status epilepticus, intracranial pressure

Benzos Risks: ↑risk of delirium, ↑duration of mechanical ventilation, ↑ICU/hospital length of stay - not first-line sedation
Place: status epilepticus, alcohol withdrawal, deeper sedation (paralytics, vent dyssync), chronic med, hemodynamic instab

midazolam* 1-2 hrs	continuous: 1-10 mg/hr intermittent: 1-2 mg IVP q2h	accumulation in renal and hepatic impairment
lorazepam 6-8 hrs	continuous: 0.5-6 mg/hr intermittent: 1-2 mg IVP/PO q2h	propylene glycol toxicity (with CI and higher doses)
diazepam 2-8 hrs	continuous: n/a intermittent: 5-10 mg IVP/PO q6-8h	accumulation in renal and hepatic impairment quick onset, long acting (active metabolite)

dexmedetomidine	continuous: 0.2-1.5 mcg/kg/hr	bradycardia, hypotension, heart block light sedation/*no resp depression (no ventilation needed); *no delirium
ketamine	continuous: 0.5-2 mg/kg/hr	hallucinations, hypertension analgesic + sedative
propofol* quick onset short dur	continuous: 5-80 mcg/kg/min	hypotension, hyperTGs, resp depress, PRIS (prop-rel infusion syndrome) quick onset, short duration; lipid emulsion; must be ventilated

Implement non-pharmacologic interventions (bed positioning, day-night cycles, etc.)
Identify and correct underlying cause (pain, sleep disturbances, delirium, etc.)
- Treating pain first is most important when addressing agitation (analgosedation)
Target light sedation with lowest effective dosages & minimal benzodiazepines

Delirium
causes: pain, lines/tubes, immobility, ICU environment, sleep/wake disturbances, withdrawal, medications, procedures
medications associated with delirium: benzos, anticholinergics, corticosteroids
complications: incr length of stay/costs, incr agitation + longterm cognitive, incr mortality/duration mechanical ventilation

hyperactive: irritable, angry, restless, combative/violent, uncooperative, nightmares, inappropriate behavioral response (i.e. laughter)
hypoactive: lethargic, apathetic , depressed, anorexia, sleep pattern disturbances, altered speech/mental status, decr alertness/awareness

CAM-ICU (+ or -): Confusion Assessment Method-ICU
1. acute changes/fluctuating mental status 2. inattention (letters) 3. altered level of consciousness (RASS level) 4. disorganized thinking (questions)

Nonpharm - treat underlying cause or disease - daily spontaneous awakening, breathing trials
- early mobilization -optimize senses (glasses, hearing aids, etc.)
- sleep hygiene - optimization of analgesic and sedative agents

	Dosing	QTc	Sedation	Antichol
haloperidol	2-5 mg IV q4h prn	moder	low	low
olanzapine	2.5-10 mg PO QD	low	moderate	moderate
quetiapine	12-5-100 mg PO BID	low	moderate	moderate
risperidone	0.25-1 mg PO/ODT BID	low	low	low

haloperidol ("There is no evidence that treatment with haloperidol reduces duration of delirum.")
Pharm no role in preventing/treating/reducing duration of delirium in patients with ***hypoactive*** delirium.
Prevention is key: nonpharmacologic interventions are first line
None have shown to reduce duration or prevent delirium; may be beneficial in **hyperactive** delirium to prevent harm

"Dry" Euvolemic

"Wet" (Congestion, ↑PCWP, volume overload)
- SOB, dyspnea on exertion, orthopnea, PND
- edema (peripheral/pulmonary), weight gain
- JVD, S3 gallop, pulmonary rales, pleural effusions
- elevated BNP/NT-ProBNP, congestive hepatopathy (↑INR LFTs)

Cardiac Output	Volume Status (PCWP)
I "Warm & Dry"	II "Warm & Wet"
III "Cold & Dry"	IV "Cold & Wet"

"Warm" Adequate Perfusion

"Cold" (↓CO, low output, Hypoperfusion)
- fatigue, sx hypotension, cool extremities
- tachycardia, narrow pulse pressure
- early satiety, nausea, anorexia
- altered mental status, hyponatremia

Subset I "Warm & Dry"
goal: provide sx relief
maintain or increase: ACE/ARB, βBlocker, MRA

Subset II "Warm & Wet"
goal: remove fluids, net neg 1-2L/day, relieve dyspnea
IV furosemide (20mg IV = 40mg PO = T20PO = B1PO); 2-2.5x home dose
increase dose, increase frequency, change to continuous CI
add metolazone to overcome resistance
IV vasodilator nitroglycerin to relieve acute dyspnea
maintain: ACE/ARB, βBlocker, MRA

Subset III "Cold & Dry"
goal: ↑CO
IV inotrope if sx hypo or SBP <90 or end organ dysfunction
if above absent, consider IV vasodilator and change to inotrope
reduce or withdraw: ACE/ARB, βBlocker, MRA

Subset IV "Cold & Wet"
goal: ↑CO, remove fluid; "warm them up to dry them out"
IV inotrope + IV diuretics if sx hypo or SBP <90 or end organ dysfunction
if above absent: IV diuretics +/- IV vasodilator
withdraw: ACE/ARB, βBlocker, MRA

βblocker: signs cardiogenic shock (low CO, end organ dysf); sx hypo/brady (SBP<90 HR<50); dose reduce before dc
ACE/ARB: cardiogenic shock, sx hypo (SBP<90), AKI, hyperkal
MRA: renal dysfunction, hyperkalemia
SGLT2: CrCl <25, DKA risk (inf, NPO, surgery)
ivabradine: cardiogenic shock, sx hypo/brady; new afib

F – Failure to comply with fluid/sodium restriction
A – Arrhythmia (atrial fibrillation), Apnea (sleep)
I – Ischemia (MI), infection
L – Levothyroxine – hyper/hypothyroidism
U – Uncontrolled HTN
R – Renal Failure
E – Embolus (pulmonary), Electrolyte disturbance
D – Drugs: associated with worsening HF
– NSAIDs – Corticosteroids – Thiazolidinediones – NonDHP CCBs
– Probenecid, Bile Acid Sequestrants – New initiation/titration of BB
– Anti-arrhythmics that are negative inotropes, decrease CO further (Class I - quinidine, propafenone; Class III - dronedarone)

Neurohormonal Model of HFrEF
underlying cardiomyopathy manifests as decreased cardiac output:
1. ↑activation of the sympathetic nervous system (baroreceptors) leading to downstream to ↑HR ↑contractility, ↑vasoconstriction
2. ↓renal perfusion in kidneys, ↑activation renin-angiotensin RAAS system further ↑vasoconstriction and ↑circulating blood volume (fluid retention)

Short term GOOD: maintain BP, ↑SV/CO
Long term BAD: congestive sx, ↑afterload, ventricular remodeling

Management of STEMI/NSTEMI/UA – MONAB
STEMI
Primary PCI within <120 min
1. UFH/LMWH/bival as adjunct to PCI
2. ASA325mg x1
3. LD ticag/prasugrel/clop
4. Stent (BMS/DES)
5. +/- GP IIb/IIIa inhibitor (inadequate LD antiplatelet)

→ continued CP? rescue PCI

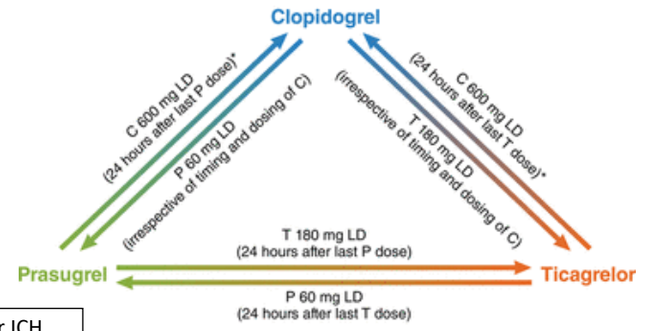
Fibrinolytics if no PCI in 120 min, sx <12h of medical contact, STEMI
1. Fibrinolytic therapy started
2. ASA325mg x1
3. clopidogrel 75-300mg
4. UFH/LMWH/fondaparinux for 48hrs

Fibrinolytics
Indication: sx ACS <12h medical contact
Contraindications
Hx hemorrhagic stroke; or other strokes within <1yr
Hx intracranial hemorrhage
Active internal bleeding
Suspected aortic dissection
Precautions: Severe uncontrolled HTN (BP>180/100), Current use of anticoagulants in therapeutic dose (INR 2-3), Recent trauma (2-4 wk), head trauma prolonged CPR, major surgery(<3 wk), Noncompressible vascular punctures, Recent internal bleeding (2-4 wk), Active PUD, DOAC
Monitor: EKG, BP/HR, CBC (H/H Plts), bleed, mental

	Dose	Onset	Duration	ADE
Continuous Infusion				
clevidipine	4-32 mg/hr	2-4 min	5-15 min	HA, N, Afib, insomnia (max 1000ml/24h)
nicardipine	5-15mg/hr	5-10	15-30->240	Tachycardia, HA, flushing, local phlebitis
nitroglycerin	5-100mcg/min	2-5	5-10	HA, V, methemoglobinemia, tolerance
labetalol	0.5-2mg/min	5-10	180-360	V, scalp tingle, bronchoconstrict, OH dizzy, heart block
Intravenous Bolus				
hydralazine	10-20mg	10-20	60-240	Tachycardia, HA, N, flushing, aggravation of angina
labetalol	10-20mg	5-10	180-360	V, scalp tingle, bronchoconstrict, OH dizzy, heart block

SAH BP Prior to securing aneurysm goal is SBP <140; utilize same agents as you would for ICH
After securing aneurysm goal is SBP <220 (after no more bleeding risk, let BP ride up due to risk of vasospasm; let BP rise so adequate distal perfusion)

Switching Between Oral $P2Y_{12}$ Inhibitors



UFH: bolus 60 u/kg (max 4000u), continuous 12 u/kg/hr for 48h or end of PCI
LMWH: 1 mg/kg sc q12h; (0.3 mg/kg IV given if <2 sc doses or last dose 8-12h before PCI)
continue for 24-48h or end of PCI

ticagrelor 30min to 50% (max 88%); pre-cath (CI hx intracranial hemorrhage)
prasugrel 60min to 50% (max 79%); after stent (CI hx intracranial hemorrhage, hx TIA/stroke)
clopidogrel 2-6h to 50% (max 35%); d/c 5d prior to CABG
300mg: fibrinolytics <75yo; LD <24h from fibrinolytic; medically managed/non-stent

NSTEMI/UA
LD antiplatelet (use clopidogrel if TIA, hx stroke, intracranial hemorrhage)
ticagrelor before cath (prasugrel only after stent)
+/- GP IIb/IIIa inhibitor high risk

Stroke Computed Tomography (CT)**
Ischemic Stroke Secondary Prevention
Main: BP <140/90, statin, exercise, DM control, diet (Na 2.4g/day), sleep apnea, alcohol, smoking, OAC with Afib
Statins: Secondary Prevention; Clinical ASCVD (post-stroke goal LDL <70)
Antiplatelets
TIA: no prev therapy = ASA + clopidogrel x21d (better than ASA alone); prev on ASA = add clopidogrel (lacks evidence)
AIS: ASA 50-325mg monotherapy; ASA 25mg + dipyridamole 200mg bid; clopidogrel 75mg qday (alternative to ASA/ASA-dipyridamole)

tPA Stroke alteplase 0.9 mg/kg IV (max 90mg); 10% IV bolus over 1min, infuse rest over 60min
Indication: sx onset <3h, BP <185/110
Contraindications
evidence of ICH
within last 3 months: ischemic stroke, severe head trauma, intracranial/intraspinal surgery
high clinical suspicion of SAH
GI malignancy or GIB within 21 days
coagulopathy (bleeding diathesis): platelet <100k, INR >1.7, aPTT >40s, or PT >15s
LMWH within 24hrs
NOAC within 48hrs with normal renal function [chart explaining half-life in renal impairment]
GPIIb/IIIa inhibitors (eptifibatide, tirofiban)
Monitor: STOP and obtain a CT if patient develops severe headache, acute hypertension, nausea, vomiting, neurologic
No Bleed: continue tPA Bleed: cryoprecipitate 10 units and TXA 1g or AMICAR 4-5g (to reverse tPA effect on plasminogen)
Monitor BP, neurologic function, bleeding: q15min during and after infusion x2hrs; q30min x6hrs, q60min x16hrs
Follow-up CT or MRI 24hrs after tPA administered

*AIS: Risk Factors
NonModifiable: Age* (risk doubles each decade after 55yo); race (black 2x>white), FH stroke, hx stroke/TIA, gender (men>women)
Modifiable: HTN* (7x risk; BP <120/80 have half lifetime risk); DM (2x risk), CAD/CHF (2x risk), smoking (2x risk), others (estrogen, hypercoag, HA, diet, OSA, MHA, PFO)
Afib: 2019 AHA: For patients with AF and an elevated CHA_2DS_2-VASc of ≥2 in men and >3 in women, oral anticoagulants are recommended

AIS: BP goals received tPA <180/<105 no tPA no thrombectomy: <220/<120 no tPA + thrombectomy: SBP <160 hemorrhagic conversion: SBP <160
AIS: BP treatment labetalol 10-20mg **IVP** (double dose if repeated, max 300mg at once) hydralazine 10-20mg **IVP** nicardipine initial 5mg/hr **IV gtt**, titrated up by 2.5mg/hr q5min (max 15mg/hr) clevidipine initiate 4mg/hr **IV gtt**, titrate by doubling dose q2-5min (max 32mg/hr or 1L/24hrs--risk of TGs)
Other therapies O2 >94%, Temp <38C, euvolemia, Na 135-145, BG 140-180 ASA81 within 24-48h
BP control (reduce 15% during first 24h; <140/90 once neuro stable) VTE prophylaxis after 24h

ICH Risk factors ***SBP goal <160 mmHg for most ICH**
Nonmodifiable: >55yo, Male, AA/Japanese, cerebral amyloid angiopathy (CAA)
Modifiable: HTN, alcohol, smoking, sympathomimetic use, anticoag use

*Severity scale – ICH Score 0-6 points
GCS (3-4 = 2 5-12 = 1 13-15: 0)
Age (≥80=1)
Bleed (infratentorial=1): pons, cerebellum
ICH vol (≥30cc=1)
intraventricular blood (yes=1)
30-day mortality: 0-0%, 1-13%, 2-26%, 3-72%, 4-97%, 5-100%, 6-100%

SAH Vasospasm management
Complication: Vasospasm is consistent vasoconstriction of the artery secondary to blood surrounding the vessel
• Most likely to occur 4-21 days after ictus • Vasospasm leads to delayed cerebral ischemia (DCI)
***nimodipine** (Nimotop, Nymalize); lipid-soluble CCB; does not reduce vasospasm incidence; however, it significantly reduced DCI by 34% (improves morbidity)
Dose: 60mg PO q4h x21 days BBW: enteral administration only
ADE: hypotension; may reduce to 30mg PO q2h

https://derangedphysiology.com/main/required-reading/miscellaneous-topics/Chapter%201.0.0/elements-routine-care-icu-fasthug
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3203830/

FASTHUG – **F**eeding, **A**nalgesia, **S**edation, **T**hromboembolic Prevention, **H**ead of Bed Elevation, Stress **U**lcer Prophylaxis, **G**lucose Control

Feeding
- Consequences of malnutrition
  - Impaired immune system function, Increased Infections
  - Poor wound healing
  - Increased decubitus ulcers
  - Disruption to GI Microbiota
  - Nutrient losses in stool
- Feed Early if hemodynamically stable: Initiate enteral nutrition within 24-48 hours; In well nourished adults wait 7 days to initiate TPN

Analgesia and Sedation
↓ • Anxiety • Ventilator dyssynchrony • Disloding lines or devices
↑ • Prolonged ventilator requirements • Inability to assess patient • Unable to mobilize patient • Delirium

Thromboembolic Prevention
- Venous Thromboembolism (VTE) common serious complications: Deep Vein Thrombosis (DVT), Pulmonary Embolism (PE)
- ~10% of hospital deaths attributed to PE
- Virchows Triad for Risk
  – Surgery – Trauma – Immobility – Malignancy – Age – Heart or Respiratory failure – Obesity – Smoking – Central Venous Catheters
- Heparin 5000 units Subcutaneous (SQ) q8h
- Enoxaparin 40 mg SQ q24h
- Enoxaparin 30 mg SQ q12h high risk
- Mechanical Methods: Intermittent Pneumatic Compression, Venous foot pumps

Head of Bed Elevation
- Reduce incidence of, Gastroesophageal reflux, Nosocomial Pneumonia, Aspiration of gastric contents and Pneumonitis

Stress Ulcer Prophylaxis
- Not all patients need stress ulcer prophylaxis: consider low Plt, high INR, PTT; mechanical ventilation >48hrs, hx GI, trauma brain/SC, burn; nsaids or antiplatelets
- Primary pharmacotherapy Agents: H2 Antagonists IV/NG/PO (Famotidine, Ranitidine); Proton Pump Inhibitors IV/NG/PO (Typically only daily)
- Inhibiting Gastric Acid Secretion HAS risks: Bacterial overgrowth, Pneumonia, Clostridioides Difficile

Glucose Control
- Hyperglycemia in ICU patients increase Morbidity & Mortality: Decrease wound healing, Increased infection risk, Impaired GI Motility, Risk Acute Kidney Injury
- Hypoglycemia increase risk of mortality
- Target glucose between 100-180 mg/dl
- Management: Sliding scale regular insulin typically ever 6 hours if NPO; Insulin infusion for glucose > 200 mg/dL

		ANC = [(%neutrophils) + (%bands)] x WBC	
Hb	F12-15 M13-17	↑Polycythemia ↓Anemia	
Plt	150-400k	↑Thrombocytosis ↓Thrombocytopenia	
WBC	4-10k w/ bands	↑Leukocytosis ↓Leukopenia (ANC <1000 ↓Neutropenia) ↑Leukocytosis with left shift	
MCV	80-100	↑Macrocytic ↓Microcytic	
Hct [35-50] Haptoglobin [36-195]		Ferritin [15-300] Serum iron [50-170] TIBC [250-370] Cobalamin [200-900] Folate [5-16]	
Hemolysis		↓Hb ↓Hct **↓haptoglobin**	
Anemia of iron deficiency		↓Hb ↓Hct **↓MCV** **↓ferritin** **↑TIBC** ↓serum iron	if normal ferritin = anemia of chronic disease
Anemia of chronic disease		↓Hb ↓Hct —MCV —/↑ferritin ↓TIBC ↓serum iron	ferritin normal/high
Anemia of chronic kidney CKD		↓Hb ↓Hct —MCV —/↑ferritin ↓TIBC ↓serum iron; Burr cells	ferritin normal/high; normal MCV+haptoglobin
Anemia of cobalamin defic		↓Hb ↓Hct **↑MCV** ↓Cobalamin	
Anemia of folate deficiency		↓Hb ↓Hct **↑MCV** ↓Folate	

Hyperkalemia		
calcium gluconate	3g IV	stabilizes myocardium
regular insulin	10u IV	shifts K intracellular
albuterol	10-20mg inh	shifts K intracellular
sodium bicarbonate	50mEq IV	shifts K intracellular
furosemide	20mg IV	inhibits Na-K-Cl transporter; **removes K**
sodium polystyrene sulfonate	30-45g PO	Na-K exchanger; **removes K** (4-6h)

Reversible Causes
- Hypoxia
- Hypovolemia
- Hydrogen ion
- Hypo/Hyperkalemia
- Hypothermia
- Toxin
- Tamponade (cardiac)
- Tension Pneumothorax
- Thrombosis (pulmonary)
- Thrombosis (cardiac)

ACLS: Asystole/PEA
- Non-shockable rhythm
- Pulse and rhythm check every 2 minutes
- Medications
  - Epinephrine 1mg every 3-5 minutes
  - Vasopressin 40 units (alternative to second epinephrine dose)
- Treat underlying cause!!

ACLS: VT/VF
- Shockable rhythm
- Pulse and rhythm check every 2 minutes
- Medications
  - Epinephrine 1mg every 3-5 minutes
  - Vasopressin 40 units (alternative to second epinephrine dose)
  - Amiodarone: First dose: 300mg, Second dose: 150mg
  - Lidocaine: First dose 1-1.5mg/kg, Second dose 0.5-0.75mg/kg
- Treat underlying cause!!

***Vitamin K** (phytonadione) 1st target
Dose: 10mg IV at 1mg/min (**know this dose)
MoA: normalizes INR by providing necessary substrate to synthesize factors II VII IX X
Limitations: slower reversal; reduction of INR to <1.4 may take up to 24hrs
Advantage: vitamin K provides sustained and durable reversal of warfarin activity and is recommended to give in conjunction with other reversal agents
***Kcentra** (prothrombin complex concentrate **PCC**; 4-factor, unactivated) 2nd target
Dose: INR <4: 25 units/kg INR 4-6: 35 units/kg INR >6: 50 units/kg (max weight 100kg)
MoA: replaces factors II IX X and unactivated VII
Limitation: the most serious adverse reaction is the risk of thrombotic events including stroke, DVT, PE
Advantage: fast reconstitution and administration, low volume compared to FFP, **rapid** INR reversal

Acid-Base

pH <7.35	↑CO2	Respiratory Acidosis
pH <7.35	↓HCO3	Metabolic Acidosis
pH 7.35-7.45		Normal, Compensated, or Mixed
pH >7.45	↓CO2	Respiratory Alkalosis
pH >7.45	↑HCO3	Metabolic Alkalosis

Expected compensation

Disorder	Compensation	
Metabolic Acidosis	Winter's formula: PaCO2 = 1.5(HCO3) + 8 ± 2	
	For each change in PaCO2 (relative to 40 mmHg)	**Change in HCO3**
Respiratory Acidosis		
Acute	↑10 mmHg	↑1 mEq/L
Chronic	↑10 mmHg	↑4 mEq/L
Respiratory Alkalosis		
Acute	↓10 mmHg	↓2 mEq/L
Chronic	↓10 mmHg	↓5 mEq/L

ROME – metabolic = equal direction
ROME – respiratory = opposite direction

	pH	PaCO2	HCO3
Respiratory Acidosis	↓	↑	↑
Respiratory Alkalosis	↑	↓	↓
Metabolic Acidosis	↓	↓	↓
Metabolic Alkalosis	↑	↑	↑

Respiratory Acidosis Etiologies
*COPD, central resp depress (sedation), airway obstruction, ARDS, pneumothorax, thoracic cage injury, rate too low on ventil

Metabolic Acidosis Etiologies normal anion gap <12
Anion gap MA [Na – (Cl + HCO3)] MUDPLIES: Methanol, Uremia, Diabetic ketoacidosis, Propylene glycol, Isoniazid/Iron, Lactic acid, Ethylene glycol, Salicylates
Nonanion gap MA (ACCRUED): Aldosterone inh, Compensation, Carbonic anhydr inh, Renal tubular acidosis, Ureteral diversion, Extra alimentation TPN, Diarrhea

Metabolic Alkalosis Etiologies
Chloride responsive (U_{Cl} <10): vomiting, nasogastric suctioning, previous diuretic use
*overall depletion of chloride
Chloride unresponsive (U_{Cl} >20): current use of diuretics, refeeding syndrome (hypokalemia), excess mineralocorticoid
*overall focused on hypokalemia that causes reabsorption of bicarb in proximal tubule

Compensation
Respiratory: Response observed within minutes of acid-base derangement; Full compensation seen within hours
Renal (metabolic): Initial response occurs within 6-12 hours after derangement; Full compensation may take 3-5 days

Physiological Values

Parameter	Normal	Where can be found?
pH	7.35-7.45	arterial blood gas
PaCO2	35-45 mmHg	arterial blood gas
HCO3	22-26 mEq/L	chemistry/arterial blood gas
Na	135-145 mEq/L	chemistry
Cl	96-106 mEq/L	chemistry
lactate	<2 mEq/L	chemistry

NMBA	RASS -4 to -5 prior to initiation		sugammadex reversal roc/vec			
succinylcholine	depolarizing Onset 15-30s Dur 5-10min 1 mg/kg IV (one time dose for intubation)			Malignant Hyperthermia: rare genetic, rigidity, fever, ischemia, v-arrhy Muscle weakness, fasciculation, ↑IOP/ICP, hyperkalemia		CI: hyperkal, burn, crash, denervating injury (SC) Malignant Hyperthermia tx: dantrolene
pancuronium						
vecuronium						
rocuronium						
atracurium						
cisatracurium						
Misc						
propofol	sedation no amnesia/analgesia; onset 1-2min, quick offset			resp depression, decreased BP/CO, hyperTGs, pancreatitis, infect		**PRIS** brady, hypo, dyslip, rhabd, met acid, fatal
dexmedetomidine	α2 agonist, onset 5-30min, use <24h in ICU			hypotension, bradycardia, NV, heart block, no resp depress		
ketamine	hyponotic+analgesic			halluc, HTN, tachy, emergence rxns, ICP		
etomidate	hyponotic, for procedures; onset 10-20sec, duration 4-10min			myoclonus, tachy but no BP/CO, seizure threshold, cortisol dec		

	Dosing	Elimination	HL min	Metab	Adverse Effects	Cost	Avoid Use In
pancuronium	LD 1, 1-2 mcg/kg/min	renal hepatic	100-300	Yes	Histamine release, Vagolytic, Tachycardia, HTN	$	CAD, liver/renal dysfunction
vecuronium	LD 1, 1-2 mcg/kg/min	renal hepatic	80-300	Yes	Bradycardia, Prolonged blockade on discontinue	$$	liver/renal dysfunction
rocuronium	LD 6-12, 10-15 mcg/kg/min	renal hepatic bile	80-130	Yes	Some histamine release but less CV effects	$$	liver/renal dysfunction
atracurium	LD 3, 5-15 mcg/kg/min	Hofmann/ester hydrolysis	20-25	No	Histamine release	$$$	possibly hypotension?
cisatracurium	LD 1, 3-5 mcg/kg/min	Hofmann/ester hydrolysis	20-30	No	No significant histamine release or CV effects	$$$$$	none

Long Term ADEs: most common with panc/vecur
Prolonged Neuromuscular Blockade
Critical Illness Myopathy/ICU Acquired Weakness

PK Changes to Critical Illness

↑CO Cardiac Output = ↑CL = ↓Cp
Leaky capillaries or altered PPB = ↑Vd = ↓Cp
Normal organ function = unchanged Vd = normal Cp
End organ dysfunction (renal/hepatic) = ↓CL = ↑Cp

Absorption Highlights

- When changing medications from IV to PO it is important to look up the IV to PO conversion
- Enteral feeds can interact with medications administered via the enteral route:
  - Enteral feeds can increase the pH of the stomach reducing the absorption of drugs that need an acidic environment for absorption
  - Tube feed ingredients can directly bind to some drugs causing decreased absorption (i.e., phenytoin, ciprofloxacin)
- To overcome drug and nutrient interactions enteral feeds can be held 1 hour before and 2 hours after drug administration
  - To avoid underfeeding, tube feed rates should be adjusted so patients can receive the total daily caloric goal

Context Sensitive Half Life
Accumulation of lipophilic drugs in the deep adipose compartment causes longer duration of action than can be explained by the medications half lives; (context = infusion duration)

Distribution Highlights

- In critically ill patients with hypoalbuminemia, drugs like phenytoin, valproic acid, and ceftriaxone that are highly protein bound will have a greater free fraction of free drug, leading to increased pharmacologic effects even if the total drug level remains unchanged
- When possible, in the critically ill, drugs that are highly protein bound should be monitored by free levels instead of total levels • Consider increased dosing

Transformation of parent compounds into metabolites: Liver (primary site), GI tract, Kidneys, Lungs, Brain
Several alterations in critical illness: Hepatic enzyme activity, Protein binding, Hepatic blood flow
Metabolism: Hepatic Blood Flow
Increased hepatic blood flow and metabolism: Early sepsis (increased cardiac output), Vasodilator use (i.e., nitroprusside), Inotropes
Decreased hepatic blood flow and metabolism: Late sepsis (decreased cardiac output), Hypovolemic shock, Myocardial infarction and acute heart failure, Vasopressor use
Metabolism: Hepatic Enzyme Activity
Many critically ill states will results in an increased hepatic metabolism: Traumatic brain injury, Burn patients
Decreased activity of CYP450 enzymes occur during stress response: Prolonged effects of parent compounds, Reduced effects of prodrugs, Increase in toxic metabolites
Medications eliminated renally most impacted: Proportional to glomerular filtration rate or CrCl
Consider true CrCl collection/measurement: Challenging to assess due to fluctuations and fluid shifts; Consider true CrCl as opposed to calculations in some populations
Altered elimination in critically ill patients: Reduced clearance (kidney injury or failure); Augmented clearance
Augmented Renal Clearance
Hyperdynamic = ↑CO = ↑renal blood flow = ↑GFR
CrCl >130 ml/min (20-65% of critically ill); physiological mechanism poorly delineated; Associated with subtherapeutic concentrations of renally-eliminated drugs
Effects of PK Alterations of Cp
PK/PD Alterations: CRRT
Vd should be primary PK consideration for initial dosing: Critical illness, sepsis, AKI, CHF/reduced EF all potential factors
Remaining CLR and CLNR dictate maintenance dosing
CRRT clearance affected by protein binding, absorption, and CRRT settings
CRRT clearance will vary based on mode: CVVH – convective removal; CVVHD – diffusion of solute across filter membrane down a conc gradient; CVVHDF – combines both properties
Decreased CRRT clearance if: Large molecule, Highly protein bound, Vd > 1.5 L/kg
Factors Affecting Elimination
Clinical Implications
Antimicrobial success dependent on early initiation, appropriate selection, and dosing to attain PK/PD target
Negative impact on therapeutic level attainment
Affects renally cleared drugs, including B-lactams, vancomycin, & AG
Enhanced drug clearance will lead to shorter half-life, lower Cmax, and smaller AUC
May compromise drug efficacy and promote drug resistance

Elimination Highlights

- Commonly critically ill patients combat multi-organ failure as a complication of their critical illness
- Patients should be monitored closely for increased or decreased renal function
- Consider therapeutic drug monitoring via drug levels or therapeutic effect for renally-eliminated medications
- Medications that are cleared primarily by the kidneys should be evaluated for following: Dose, Interval, Therapeutic drug monitoring (drug levels or associated labs i.e. anti-Xa)

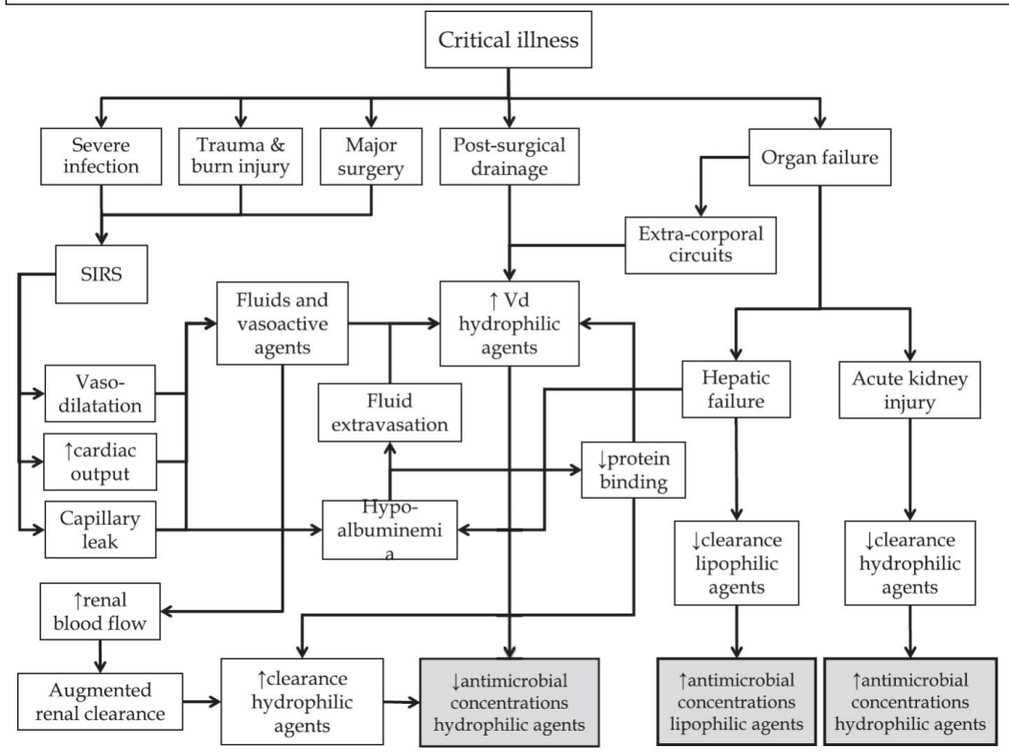
*ASA81 Takeaway: ASA no role in primary prevention
USPS Task Force: men no reduction in stroke (reduces MIs); women 55-79yo recommended for stroke prevention
AHA 2014: ASA for CV prevention reasonable with 10yr risk >10%
ASCEND: controlled DM (A1c <8) ASA reduces serious vascular events but increased major bleeding
ASPREE: >70yo ASA did not reduce disability-free survival but associated with higher major hemorrhage and all-cause mortality
ARRIVE: moderate-risk (10yr CV risk 10-20%), ASA did not reduce CV events but doubled GI bleeding

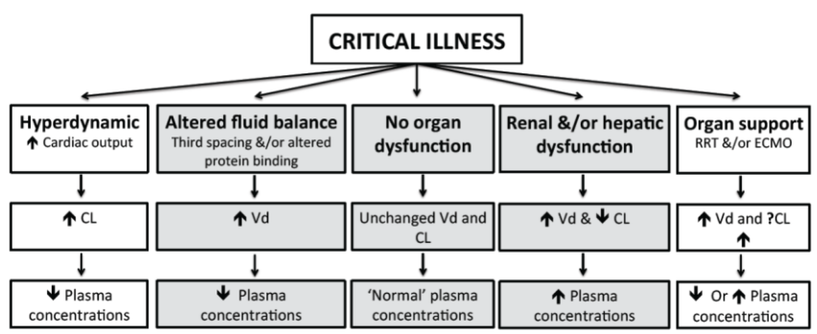
Rapid Sequence Intubation (RSI)

- Utilized to facilitate intubation in patients with respiratory compromise
- Utilization of pre-specified sequential steps including sedation followed by paralyzing agent
  - **SEDATION ALWAYS GOES FIRST!**
- Used to prevent aspiration and reduce sympathetic effects
- Optimal medication selection is imperative to reduce side effects

RIS Medications

	Onset	Duration	ADEs
Sedatives			
etomidate (GABA-A)	10-20 sec	4-10 min	myoclonus, adrenal suppression
ketamine (NMDA antag)	1-2 min	5-10 min	emergence phenomena, increased sympathetic response
propofol (GABA-A)	1-2 min	5-10 min	hypotension
midazolam (GABA-A)	3-5 min	1-2 hr	hypotension (less than propofol)
Paralytics			
succinylcholine (depolarizing)	15-30 sec	5-10 min	hyperkalemia
rocuronium (nondepol)	1-2 min	30-45 min	prolonged paralysis in hepatic failure
vecuronium (nondepol)	2-3 min	45-60 min	prolonged paralysis in hepatic/renal failure





hypoNa = edema; s/s: neuro (HA, AMS, stupor, seizures), muscle twitch, NV
hyperNa = dehydration; s/s: SALT (skin flushed, agitation, low grade fever, thirst), neuro
hypoK = s/s: muscle weakness, constipation; weak pulse, OH, numbness
hyperK = renal failure?; s/s: EKG peaked T waves and shortened QT, irritation, parathesia, muscle leg weakness; irreg pulse, hypotension, ND, abd cramps
hypoMg = s/s: CVS (tachy, HTN, EKG); CNS (confusion, halluc, alt conscious), neuromuscular weakness/cramps, GI dysphagia, NV anorexia
hyperMg = s/s: decreased neuromusclar, general weakness, NV
hypoCa = s/s: diarrhea, neuromusc (anxiety, confusion, irrit, muscle twitch, parathesias); fractures, EKG, tetany, decreased response to digoxin
hyperCa = s/s: constipation, fatigue, confusion, lethargy, hyporeflexia, bradycardia (SCA), NV, polyuria, anorex, muscle weakness
hypoPhos = s/s: HTN, ↓CO, hemotalogic anemia, bruise, infection; CNS confusion, anxiety, seizure, muscle weakness, respiratory; fractures
hyperPhos: cardiac irreg, hyperreflexia, poor diet, muscle weak, oliguria
hypoCl = s/s: agitation, irrit, cramps, hypertonicity, resp slow, seiz, arrhythmias
HyperCl = s/s: HTN, tachy, edema; metabolic acidosis, ↓LOC, weak, hypernet, agit

Electrolytes

		Symptoms	Treatment
Water			
- Dehydration		- irritability, confusion, dizzy, weakness, fever, dry skin, sunken eyes - thirst, ↓urine, tachycardia, poor skin turgor	- isotonic dehyd: H2O+electrolyte in equal amounts (diarrhea, vomit) - hypertonic dehyd: H2O loss greater than electrolyte loss (excessive perspiration, diabetes insipidus) - fluid replacement, monitor s/s vitals, daily weights, skin/mouth care
- Hypovolemia		- mental, thirst, tachy, orthostatic HTN, cool pale extremities - weight loss, delayed capillary refill, ↓urine	- fluid replacement, albumin replacement - dopamine to maintain BP, blood transfusion for hemorrhage
- Hypervolemia		- tachypnea, dyspnea, HTN, weight gain, edema, CVP and pressure	- fluid/Na restriction, diuretics, monitor vitals and breathing
Sodium			
- Hyponatremia	35 –	- primarily neurological, HA, N/V, muscle twitch, AMS, stupor, seizures, coma - can have hypovol and hypervol symptoms as well	- mild: restrict fluid intake for hyper/isovolemic; IV fluids and increase Na for hypovolemic - severe: infuse NaCl solution; furosemide to remove excess fluid
- Hypernatremia	145	- SALT: skin flushed, agitation, low grade fever, thirst - neurological symptoms, signs of hypovolemia	- correct underlying disorder, gradual fluid replacement, monitor cerebral edema and Na levels - seizure precautions
Potassium			
- Hypokalemia	3.5 –	- muscle weakness, EKG changes, constipation, toxicity digoxin - irregular, weak pulse, orthostatic HTN, numbness (parathesias)	- increase dietary K+ (oral KCl), change to K-sparing diuretic - IV K+ replacement, monitor EKG changes
- Hyperkalemia	5.0	- irritability, parathesia, muscle weakness (esp legs), EKG changes (T) - irregular pulse, hypotension, nausea, diarrhea, abdominal cramps	- mild: loop diuretics, dietary restriction - moderate: kayexalate - severe: 10% calcium gluconate for cardiac effects, Sod bicarb for acidosis
Magnesium			
- Hypomagnesemia	1.5 –	- CNS (alt. conscious, confusion, halluc), neuromuscular weak/cramps - CVS (tachy, HTN, EKG), GI dysphagia, anorexia, N/V	- mild: dietary replacement - severe: IV/IM magnesium sulfate; monitor neuro, cardiac, safety
- Hypermagnesemia	2.5	- decreased neuromuscular activity, general weakness, N/V	- increased fluids if renal normal, loop if nonresponsive to fluids, calc. gluconate for toxicity, ventilation, HD
Calcium			
- Hypocalcemia	8.9 –	- neuromuscular: anxiety, confusion, irrit, muscle twitch, parathesias - fractures, diarrhea, decrease response to digoxin, EKG, tetany	- calcium gluconate; cardiac monitoring - oral or IV calcium replacement
- Hypercalcemia	10.1	- fatigue, confusion, lethargy, coma, muscle weakness, hyporeflexia - bradycardia (SCA), anorex, N/V, constipation, polyuria, renal calculi	- underlying cause if asymptomatic, hydration to encourage diuresis; loop diuretics, corticosteroids
Phosphate			
- Hypophosphatemia	2.5 –	- CNS confusion, anxiety, seizure, coma; muscle weakness, respiratory - HTN, ↓CO, pathological fractures; hemotalogic anemia, bruise, infect	- mild/moderate: dietary interventions, oral supplementation - severe: IV replacement using potassium phosphate or sodium phosphate
- Hyperphosphatemia	4.5	- cardiac irregularities, hyperreflexia, poor diet, muscle weak, oliguria	- low-P diet, decrease absorption with antacids, treat underlying cause of resp acidosis or DKA, IV saline for severe
Chloride			
- Hypochloremia	98 –	- agitation, irrit, cramps, hypertonicity, resp slow, seiz, coma, arrhythmias	- treat underlying cause, oral or IV replacement in NaCl or KCl solution
- Hyperchloremia	106	- metabolic acidosis, ↓LOC, weak, hypernet, agitation, tachy, HTN, edema	- correct underlying, restore fluid, electrolyte, acid-base balance; IV lactated Ringer's to correct acidosis

heparin: the therapeutic PTT goal of 72-95 seconds (equating to 0.3-0.7 units/mL of anti-Xa activity)
UFH **ppx** 5000 units SC q8h no renal dosing weight: 7500 units SC q8h in obese **tx** 80u/kg bolus, then 18u/kg/hr (max 10000u, 2000u/hr)
LMWH **ppx** 40mg SC qday CrCl <30 30mg SC qday weight: 40mg SC q12h in obese **tx** 1mg/kg q12h CrCl <30: 1mg/kg qday weight: 1.5mg/kg q24h in obese
antixa: large patients, small patients, fluctuating renal function, clinical status (peeing blood)
lovonex ppx: 0.2-0.5 q24h; 0.2-0.4 q12h lovenox tx: 0.6-1.09

IV furosemide (20mg IV = 40mg PO = T20PO = B1PO); 2-2.5x home dose

Intro

PN indications: inaccessible GI tract, short bowel syndrome (<200cm), intestinal obstruction/ileus, high output fistulas or ileostomies (>500 ml/day)
25-30 kcal/kg of nutrition per day maintenance **IV fluid 30-40ml/kg/day**
Total body water (TBW) is calculated based on **60% of ABW**.
Gastric electrolyte loss: **Na and Cl**.
ADH is released in response to **decreased** circulating volumes.
Hyperkalemia: calcium gluconate 1g IV over 3-5min stabilize myocardium
Correct electrolytes before PN

Nutritional Support

nutrition screening 24hrs; evaluate GI tract to determine type of nutrition
Dx: (2 of) energy intake, weight loss, body fat loss, muscle mass wasting, fluid/edema, handgrip strength
Spectrum: total enteral tube feedings = shortterm (NG, ND, NJ); longterm (PEG, PEJ) > peripheral PN > total PN

Malnutrition

Starvation-related: without inflammation; anorexia, homeless
Chronic disease-related: inflammation chronic mild-mod; RA/Crohns
Acute disease/injury-related: inflammation acute severe; sepsis, trauma

Enteral Products

"If the gut works, use it!" **20-30 kcal/kg day** start at 20ml/hr titrate q2-4h; glucose infusion rate should be <4-5 mg/kg/min
initiated when inadequate oral intake is expected for **7-14 days**.
- liquid preferred; enteral contain 70-84% water; hypertonic if fluid restrict
Hydrolyzed EN indicated **impaired GI digestion or absorption**.
Renal: lower protein K Mg P Hepatic: more BCAA less AAA DM: complex less CHO COPD: less CHO, more fat ARDS: mod lipid

Parenteral Products

overarching indication for PN is a **non-accessible GI tract**; once PN is started, at least **7 days** for nutritional benefit
Indications for PN support: • Inaccessible GI • Short bowel syndrome • Intestinal obstruction • High output fistulas (>500 ml/day) • Ileus

Calories = 20-30 kcal/kg/d (~28 kcal/kg/d) **Fluid** = 30-40 ml/kg/d
ILE = 1 g/kg/d (~20-30% of cals) = **[10 kcal/g]** **CHO** = 60-75% cals = **[3.4 kcal/g]** **Protein** = 1-1.5 g/kg/d (~10-15% of cals) = **[4 kcal/g]**

Na (tonicity, fluid balance) = 1-2 mEq/kg K (muscle cardiac function) = 1-2 mEq/kg Cl/acetate (extracell acid-base) = maintain acid-base balance
Phos (energy ATP) = 20-40 mmol Ca (bone, cardiac function) = 10-15 mEq Mg (cardiac, GI function) = 8-20 mEq

Hyperglycemia most common complication of PN (BG goal 100-180); dextrose max 100g

Hypoglycemia (<60)
- Avoid rebound hypoglycemia *Administer 10% dextrose at 50 ml/hr x 2 hr OR Taper PN at 50 ml/hr x 2 hr before discontinuing

Refeeding syndrome: a complication caused by rapid nutritional repletion in a malnourished patient which drives the following electrolytes intracellularly causing ↓K Ca Phos. If left untreated, refeeding syndrome could manifest in cardio-pulmonary collapse. within 2-3d, lasts 1-2wk
Early recognition is KEY; *Must limit sources of dextrose and reduce feeding rate – go "low and slow"
*Replace electrolytes aggressively *Increase nutrition to goal gradually

T. bili is > 7, hold **trace elements** (d/t Mn accum, neurotox)
*Thiamine deficiency (Vitamin B1): *At risk patients: Alcoholic, Post bariatric surgery, Refeeding syndrome
*Wet beriberi – lactic acidosis, cardiac failure, Wernicke's Korsacoff syndrome Dry beriberi – weakness, paresthesias
*additional Zn added in diarrheal conditions or high output fistula (5-10mg) d/t wound healing
*additional Se added for cardiomyopathy/woundheal (40-60mcg)

Efficacy of PN

progress towards goal: how long to achieve goal rate, tolerating well, any complications, signs of improvement/wound healing?
24h urine-Nitrogen Balance (NB): NB = intake (NI) – ((UUN x 1.2) + 1) ***goal = +1-4g/day** NI = g AA/d divided by 6.06 UUN = urine urea nitrogen
body composition: bioelectrical impedance (body fat, lean muscle, water); hand grip test; QoL

	ADH levels	Serum Na	Plasma Osmolarity
SIADH	HIGH	LOW	LOW
Diabetes Insipius	LOW	HIGH	HIGH

Na content	Water content	Serum Na (mEQ/L)
Normal	Normal	135-144
Normal	Increased	<135
Normal	Decreased	>145
Decreased	Normal	<135
Decreased	Decreased	<135, 135-144, >145
Decreased	Increased	<135 or severe at <130
Increased	Normal	>145
Increased	Increased	<135, 135-144, >145
Increased	Decreased	>145

	Starvation	Trauma/Disease
Metabolic rate	↓	↑↑
Body fuel	conserved	wasted
Body protein	conserved	wasted
Urinary nitrogen	↓	↑↑
Weight loss	slow	rapid

	Normal	Parenteral Req.	Serious: ↓	Serious: ↑
Na	135-145	1-2 mEq/kg	<130	>150
K	3.5-5.0	1-2 mEq/kg	<3	>5
Cl	98-108	maintain acid-base		
HCO3	23-30	maintain acid-base	<18 (CO2)	>30 (CO2)
Ca	9-10.5	8-20 mEq/day	<1.2	>2.5
Mg	1.7-2.4	10-15 mEq/day	<2	>5.5
P	2.5-4.5	20-40 mmol/day	<4.4 ionized	>10 total

(CO2): evaluate blood gas for actual serum pH < 7.2 severe acidemia; > 7.6 severe alkalemia

Monitoring PN	Initiation	Critically Ill	Stable
Electrolytes	daily x 3	daily	1-2x/wk
Glucose (serum) Glucose (POC)	daily x 3 q6h	daily q6h	1-2x/wk
Wt, I/O	daily	daily	daily
Serum TG	day 1	weekly	weekly
Liver enzymes	day 1	weekly	weekly
CBC w diff		weekly	weekly
Nitrogen balance		weekly	weekly

Macronutrients

Intravenous Lipid Emulsion (ILE) = Fat **[10 kcal/g]**
Dextrose = Carbohydrate (CHO) **[3.4 kcal/g]**
Amino Acid = Protein **[4 kcal/g]**

Learned All

prealbumin nutrition: low malnourished
aeiou acute dialysis; ccrt crcl~30 q48h, hd crcl ~15
Xarelto more data with BMI 40-50 than Eliquis
ESR/CRP elevated during antimicrobials not good cuz not treating the infection; ESR CRP inflammation
hyperkalemia peaked T waves and shortened QT
headache: magox, IV Mg, caffeine, haldol, compazine (N and HA)
HD patients: PO4- and K high

SCAD pregnancy

steroids: 0.7-1dex = 5pred = 4methylpred = 20hydrocort
pred high dose >20mg need pjp; mod10-20, low <10

ATP antitachy pacing 3x then shock
LDH demand ischemia, HF hepatic congestion, trauma

nitrate decrease myocardial oxygen demand, reduces preload; false sense of security
lytics data from anterior mi young ppl
if ST higher in lead 2 than 3; nejm article
sensitive UA - S4 listen; except in afib

when down on dobut didn't diurese as well
wedge pressure 15-20: good to diurese
if dropping wedge to 15, drop bp

Hepatic (avoid codeine, hydrocodone, tramadol) 1st: hydromorphone, methadone, morphine, oxymorphone (?) 2nd: oxycodone, fentanyl, buprenorphine (?)
Renal (avoid morphine, codeine, tramadol) 1st: methadone, fentanyl, oxycodone, oxymorphone, buprenorphine 2nd: hydromorphone, hydrocodone

Glucagon-like peptide 1 (GLP-1)-based therapies reproduce or enhance the actions of the naturally occurring peptide GLP-1. They affect glucose control through several mechanisms, including enhancement of glucose-dependent insulin secretion, slowed gastric emptying, regulation of postprandial glucagon, and reduction of food intake

Drugs implicated in drug-induced thrombocytopenia: Carbamazepine, Chemotherapeutic Agents, Glycoprotein IIb/IIIa Antagonists (Eptifibatide, Tirofiban), Ibuprofen, Linezolid, Mirtazapine, Penicillins (Amox, Piperacillin, Nafcillin), Quinine, Quinidine, Oxaliplatin, Sulfa Antibiotics, Rifampin, rimethoprim, Vancomycin

acs goal 50-60bpm

acei good for anterior MI: look into data
hfpef spirono

HR<60, QT > QTc; thus use QT if HR<60
JT = QT-QRS = <330 to initiate therapy

hydral: afterload; vasodilation arterioles, little on veins; decreased systemic resistance
isdn: preload; vasodilation peripheral veins more so than arteries; reduces cardiac oxygen demand by decreasing preload (LV end-diastolic pressure); may modestly reduce afterload

Hemodynamic parameters for fluid therapy: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3159904/

IV to PO after 24hrs

high BUN AMS uremia
BNP high more fluid overloaded; normal <200
BNP is a natriuretic hormone released from myocardial cells in response to volume expansion and possibly increased wall stress
BNP and N-pro-BNP are increased in patients with heart failure and are predictors of death and cardiovascular events in asymptomatic patients without HF
BNP may increase the rate of sodium excretion and reduce the effects of the renin-angiotensin (RAS), sympathetic nervous systems (NS), and endothelin (ET)-1
BNP ↑ = reduced preload and afterload
https://www.uptodate.com/contents/image/print?imageKey=CARD%2F99857

chadsvasc ≥4 bridging-
lifevest low ef, arryhthmia, wide qrs
BUN more important to follow in dialysis
BNP high more fluid overloaded; normal <200
too much diuresis: cl down, co2 up
*chemistry: hemolyzed lab: intracellular electrolytes—K+ Mg+ PO4- would be higher than what it likely truly is

Left Heart Catheterization (LHC)
Arterial access; Aorta, left heart, coronary arteries; Various interventions employed; Uses contrast
Used to visualize coronary arteries and blockages/malformations; can then intervene on blocked arteries (balloon angioplasty, stent placement, etc.)
Limitations: Invasive procedure, risk of bleeding and complications, may not be able to intervene if extensive coronary artery disease
Pharmacy: Contrast-induced nephropathy: hydration, avoid nephrotoxinsIntra-procedure medication selection and post-procedure antiplatelet therapy

Right Heart Catheterization (RHC)
Venous access; Right heart into pulmonary artery; Takes pressure measurements; No contrast
Hemodynamic measurements: cardiac output, cardiac index, systemic venous resistance, etc.; Heart failure; Pulmonary hypertension; Cardiac biopsy
Limitations: Invasive procedure, diagnostic and monitoring only, not a treatment method
Pharmacy: Measurements can guide dosing of diuretics, arterial and/or venous vasodilators

Echocardiogram (ECHO)
Ultrasound waves reflect off tissues with differing densities to create a 2D image Transthoracic ECHO (TTE) Transesophageal ECHO (TEE) invasive
Determine size of heart structures, observe valve function and blood flow; LV ejection fraction (EF); Valve stenosis or regurgitation; Vegetation, thrombus, tumor; Patent foramen ovale; Atrial septal defect
TEE image quality generally superior to TTE, gives view from posterior side of heart; cannot observe coronary arteries
EF guides heart failure management (medications) Vegetation = endocarditis Thrombus = anticoagulation

General Review
Review progress notes; Review labs and vitals for abnormal values and trends; VTE prophylaxis; Medication monitoring (review ordered medications, drug-drug interactions, dose adjustments); Review fill history for missing medications and inaccurately ordered doses; Microbiology review (culture results, drug/bug mismatch, treatment duration)

VS (Temp, HR, BP, RR, 02)
1. Temp: THERE ARE ONLY 3 OPTIONS!!!
   - Afebrile, or Medicine fever (>100.4), or Surgery fever (>101.4)
2. HR & BP: please give me a range! Stable or changing from yesterday?
3. RR: no one cares, unless your 02 is low and/or it's hypo/hyper and leading to acid/base d/o
4. 02: Room air? Nasal cannula - How many liters? (For each L, you're adding about 3% 02 so if
   - I'm on 3L 02, my Fi02 is ~30%) Assisted? (mask, bipap, cpap, vent. . .settings? Tell me more!)
      - An 02 >92% is fine, less than this, note it! Consider oxygen.

UOP: amt. of urine in "whatever time"/pts wt in kg/"whatever time" (mL/kg/hr)
WBC: If your pt has a low white count and/or is at risk for neutropenia, calculate the absolute neutrophil count
1. ANC=(%segs+%bands)xWBC
2. What's that you say, your pt has neutropenic fever?!?
   - Plan: Cefepime x48 hrs, still fevering?
      - Vanc x5 days, still fevering? Add antifimgals!

3. If the white count is high, why? Look at the differential to see what predominates (neutrophils, lymphocytes, etc). . .don't forget, ADMIN OF 'ROlDS' → increase in white count! So don't get too excited if you just started your pt on Prednisone yesterday and all of a sudden their WBC jumps.

Hgb/Hct should be ~l:3 and >7/2l (8/24 for ObGyn and 10/30 in severe conditions)
1. Transfiising IU of pRBC59 increase of l in Hgb and 3 in Hct! KNOW THIS!
2. This means that if a pts H/H drops by 1/3, they have likely lost 1 unit of blood

Plts: Goal of >50 (clot able to be formed), consider transfusing @ <20
Na: If low, think about volume overload (the 3 "osis-es" ; if high, they're dry!
K: Know how to replace K if low and what steps to take if high!
1. HYPOK=10mEq IVéincrease in ~0.1 K, give to goal (20—40 at a time), don't go overboard
   - YOU MUST HAVE ADEQUATE Mg TO REPLETE! !!
   - If you don't have an Mg level, suggest getting one for this reason, you will look smart
2. HYPERK="C BIG K, Die"
   - C=Calcium gluconate (for heart, not actually treating K)
   - B=Bicarb, IG=Insulin/Glucose, K=Kayexalate
   - "Die"=Dialysis (last ditch effort if others aren't working!)

Cl/Bicarb: See "acid/base" below...
BUN/Cr: Calc the GFR! If your pt is on dialysis, Cr is stupid — don't get excited about it.
1. Prerenal AKI: BUN/Cr>20, FeNa<1%
2. Intrinsic AKI: BUN/Cr<15, FeNa>2%
3. Postrenal AKI: BUN/CR>15, FeNa>4%

Ca: "BUT WHAT IS THE ALBUMIN?"
1. ALWAYS correct Ca for Alb: [O.8X(4—Alb)]+Ca= your corrected Ca level

Glu: Pt diabetic or been running hypo or hyperglycernic?
1. Gimme the last 3 glucoses!!!

Scores: The following are also on MedCalc. ..
STEMI and NSTEMI: TIMI score

Pneumonia: CURB-65
Pleural effusion: Light's criteria
Pulmonary embolism: Wells Score (there is also a Wells for DVT)
Pancreatitis: Ranson's criteria and Apache II score
Liver disease: MELD score
Risk of stroke w/in lSt 2 days of having TLA: ABCD2 score
Risk of stroke in pts w/ A—Fib: CHADS2 score
Stroke: NIH Stroke Scale

Acid/Base status:

0 pHaBicarb/COZ. . .f1rst, figure out What you are dealing with. . .also, anion gap?
1. AG=Na-(C1+Bicarb). . .about 8-12 is normal
2. If you have a metabolic acidosis WITH an anion gap. . .think MUDPILES!
3. Expected C02 during a metabolic acidosis?-WINTER'S FORMULA!

Indications for emergent dialysis!!! AEI(SLIME)OU!

- A: acidosis (metabolic. . .so again go back to MUDPILES, etc.)
- E: electrolytes (mainly K)
- I: intoxication
  - SLIME (salicylates, Li+, isopropanol, Mg-containing laxatives, ethylene glycol)
- O: the "osis—es". . .Volume overload (from CHF-"cardiosis", cirrhosis, nephrosis)
- U: uremia (pericarditis, encephalopathy, and/or GI bleed may be present)

Last thing...TOP CAUSES. . .YOU WILL BE PIMPED ON THESE THINGS!!!

- Pancreatitis: MCC can be attending dependent. . .whoopsie!
  1. Gallstones (MC in women)
  2. Alcohol (MC in men)
  3. TGs (>800-lOOO)
- Small bowel obstruction (SBO):
  1. Adhesions (ask about surgical history, look for abdominal scars!)
  2. Hernia (drop the pants!)
  3. Cancer (fam history, look carefiilly for signs and symptoms)
- Post-op fever: KNOW THE TIMING!!! Usually happens in the order below...
  - Atelectasis (MCC day 1), pneumonia (hosp acquired or aspiration), UTI (how long has this foley been in?), PE/DVT, wound infection, line infection (usually >7d post-op)
- Critical limb ischemia. . .THIS IS AN EMERGENCY!
  - "6 Ps": Pain, Pallor, Poikylothermia, Paresthesias, Paralysis, Pulselessness

Vasopressors and inotropes in treatment of acute hypotensive states and shock: Adult dose and selected characteristics

Agent	Initial dose	Usual maintenance dose range	Range of maximum doses used in refractory shock	Role in therapy and selected characteristics
Norepinephrine (noradrenaline) Levophed	5 to 15 mcg/min (0.05 to 0.15 mcg/kg/min) Cardiogenic shock: 0.05 mcg/kg/min	2 to 80 mcg/min (0.025 to 1 mcg/kg/min) Cardiogenic shock: 0.05 to 0.4 mcg/kg/min	80 to 250 mcg/min (1 to 3.3 mcg/kg/min)	• Initial vasopressor of choice in septic, cardiogenic, and hypovolemic shock. • Wide range of doses utilized clinically. • Must be diluted; eg, a usual concentration is 4 mg in 250 mL of D5W or NS (16 micrograms/mL).
Epinephrine (adrenaline) Adrenalin	1 to 15 mcg/min (0.01 to 0.2 mcg/kg/min)	1 to 40 mcg/min (0.01 to 0.5 mcg/kg/min)	40 to 160 mcg/min (0.5 to 2 mcg/kg/min)	• Initial vasopressor of choice in anaphylactic shock. • Typically an add-on agent to norepinephrine in septic shock when an additional agent is required to raise MAP to target and occasionally an alternative first-line agent if norepinephrine is contraindicated. • Increases heart rate; may induce tachyarrhythmias and ischemia. • For inotropy, doses in the higher end of the suggested range is needed. • Elevates lactate concentrations during initial administration (ie, may preclude use of lactate clearance goal); may decrease mesenteric perfusion. • Must be diluted; eg, a usual concentration is 1 mg in 250 mL D5W (4 micrograms/mL).
Phenylephrine	40 to 160 mcg/min until stabilized (alternatively, 0.5 to 2 mcg/kg/min)	20 to 400 mcg/min (0.25 to 5 mcg/kg/min)	80 to 730 mcg/min (1.1 to 9.1 mcg/kg/min)	• Pure alpha-adrenergic vasoconstrictor. • May be considered when tachyarrhythmias preclude use of norepinephrine. • Alternative vasopressor for patients with septic shock who: (1) develop tachyarrhythmias on norepinephrine, epinephrine, or dopamine, (2) have persistent shock despite use of two or more vasopressor/inotropic agents including vasopressin (salvage therapy), or (3) high cardiac output with persistent hypotension. • May decrease stroke volume and cardiac output in patients with cardiac dysfunction. • May be given as bolus dose of 50 to 100 mcg to support blood pressure during rapid sequence intubation. • Must be diluted. The usual concentration is 10 mg in 250 mL D5W or NS (40 mcg/mL). Others include the following based upon volume status: 10 mg in 500 mL (20 mcg/mL) of D5W or NS, 50 mg in 500 mL (100 mcg/mL) of NS, 100 mg in 500 mL (200 mcg/mL) of NS, or 100 mg in 250 mL (400 mcg/mL) of NS.
Dopamine	2 to 5 mcg/kg/min	2 to 20 mcg/kg/min	20 mcg/kg/min	• An alternative to norepinephrine in septic shock in highly selected patients (eg, with absolute or relative bradycardia and a low risk of tachyarrhythmias). • More adverse effects (eg, tachycardia, arrhythmias particularly at doses ≥20 mcg/kg/min) and less effective than norepinephrine for reversing hypotension in septic shock. • Lower doses (eg, 1 to 3 mcg/kg/min) should not be used for renal protective effect and can cause hypotension during weaning. • Must be diluted (eg, a usual concentration is 400 mg in 250 mL D5W [1.6 mg/mL] or 800 mg in 250 mL D5W [3.2 mg/mL]); use of a commercially available pre-diluted solution is preferred.
Vasopressin Antidiuretic hormone Pitressin, Vasostrict	0.03 units/min	0.01 to 0.04 units/min (not titrated)	Doses >0.04 units/min can cause cardiac ischemia and should be reserved for salvage therapy	• Add-on to norepinephrine to raise blood pressure to target MAP or decrease norepinephrine requirement. Not recommended as a replacement for a first-line vasopressor. • Pure vasoconstrictor; may decrease stroke volume and cardiac output in myocardial dysfunction or precipitate ischemia in coronary artery disease. • Must be diluted; eg, a usual concentration is 25 units in 250 mL D5W or NS (0.1 units/mL).
Dobutamine Inotrope ($beta_1$ adrenergic) Dobutrex	Usual: 2 to 5 mcg/kg/min (range: 0.5 to 5 mcg/kg/min; lower doses for less severe cardiac decompensation)	2 to 10 mcg/kg/min	20 mcg/kg/min	• Initial agent of choice in cardiogenic shock with low cardiac output and maintained blood pressure. • Add-on to norepinephrine for cardiac output augmentation in septic shock with myocardial dysfunction (eg, in elevated left ventricular filling pressures and adequate MAP) or ongoing hypoperfusion despite adequate intravascular volume and use of vasopressor agents. • Increases cardiac contractility and rate; may cause hypotension and tachyarrhythmias. • Must be diluted; a usual concentration is 250 mg in 500 mL D5W or NS (0.5 mg/mL); use of a commercially available pre-diluted solution is preferred.
Milrinone Inotrope (PDE_3 inhibitor) Primacor	0.125 to 0.25 mcg/kg/min	0.125 to 0.75 mcg/kg/min	0.75 mcg/kg/min	• Alternative for short-term cardiac output augmentation to maintain organ perfusion in cardiogenic shock refractory to other agents. • Increases cardiac contractility and modestly increases heart rate at high doses; may cause peripheral vasodilation, hypotension, and/or ventricular arrhythmia. • Renally cleared; dose adjustment in renal impairment needed. • Must be diluted; eg, a usual concentration is 40 mg in 200 mL D5W (200 micrograms/mL); use of a commercially available pre-diluted solution is preferred.

- All doses shown are for intravenous (IV) administration in adult patients. The initial doses shown in this table may differ from those recommended in immediate post-cardiac arrest management (ie, advanced cardiac life support). For details, refer to the UpToDate topic review of post-cardiac arrest management in adults, section on hemodynamic considerations.
- Vasopressors can cause life-threatening hypotension and hypertension, dysrhythmias, and myocardial ischemia. They should be administered by use of an infusion pump adjusted by clinicians trained and experienced in dose titration of intravenous vasopressors using continuous noninvasive electronic monitoring of blood pressure, heart rate, rhythm, and function. Hypovolemia should be corrected prior to the institution of vasopressor therapy. Reduce infusion rate gradually; avoid sudden discontinuation.
- Vasopressors can cause severe local tissue ischemia; central line administration is preferred. When a patient does not have a central venous catheter, vasopressors can be temporarily administered in a low concentration through an appropriately positioned peripheral venous catheter (ie, in a large vein) for less than 24 hours. The examples of concentrations shown in this table are useful for peripheral (short-term) or central line administration. Closely monitor catheter site throughout infusion to avoid extravasation injury. In event of extravasation, prompt local infiltration of an antidote (eg, phentolamine) may be useful for limiting tissue ischemia. Stop infusion and refer to extravasation management protocol.
- Vasopressor infusions are high-risk medications requiring caution to prevent a medication error and patient harm. To reduce the risk of making a medication error, we suggest that centers have available protocols that include steps on how to prepare and administer vasopressor infusions using a limited number of standardized concentrations. Examples of concentrations and other detail are based on recommendations used at experienced centers; protocols can vary by institution.

Vasodilators	DHP CCBs	Non-DHP CCBs
Drugs:	amlodipine, nifedipine, felodipine	diltiazem, verapamil
MoA:	- blocking Ca entry into the cells by binding to L-type Ca channels	- blocking Ca entry into the cells by binding to L-type Ca channels - diltiazem: cardiac & vascular selective; verapamil: more cardiac, less vascular
Location:	L-type Ca channels in the VSM	L-type Ca channels in the VSM and heart (SA node, AV node, cardiac muscles)
CV Effects:	- vasodilation (smooth muscle relaxation)	- vasodilation (smooth muscle relaxation) - ↓ contractility and ↓ HR - ↓ AV conduction velocity
Side Effects:	- reflex tachycardia (cardiac stimulation) - flushing, headache, hypotension (as extension of vasodilation), lower-extremity edema (peripheral edema) - CYP3A4 substrates - QT prolongation	- bradycardia, impaired electrical conduction and depressed contractility - flushing, headache, hypotension (as extension of vasodilation) - CYP3A4 inhibitors - QT prolongation - contraindicated HF, Sick Sinus Syndrome
Indication:	- HTN - angina	- HTN - angina (due to ability to ↓HR); variant first-line, stable second-line - arrhythmia (due to ability to impact conduction velocity)
Therapeutics:	- sustained-release better for side effect profile - do not use in CHF - do not abruptly discontinue due to rebound effects	- many formulations available, not interchangeable - do not use in CHF - do not abruptly discontinue due to rebound effects
Monitor:	- BP and pulse (<50bpm) - signs/symptoms CHF (peripheral edema), CCBs can worsen these symptoms	- BP and pulse (<50bpm) - signs/symptoms CHF (peripheral edema), CCBs can worsen these symptoms

Ang Inhibitor	ACEIs	ARBs
Drugs:	captopril, enalapril, lisinopril, benazepril, fosinopril, ramipril	losartan, valsartan, olmesartan, irbesartan, candesartan
MoA:	- block AngI to Ang II formation by inhibiting ACE (↓ Ang II) - reduce Ang II mediated effects (reduce aldosterone) - ↑ bradykinin (by inhibiting its metabolism by inhibiting ACE)	- block angiotensin II AT1-receptors - effect of AT1 antagonists is more specific and stronger than ACEIs
Location:	kidney and lungs	kidney, intestine, VSM in endothelial cells
CV Effects:	- vasodilation (reduces arterial pressure, preload, afterload) - ↓ blood volume (promotes Na and H_2O excretion, blocking AngII in kidney stimulation of aldosterone secretion) - depress sympathetic activity (blocking AngII effects on sympathetic nerve release, and NE reuptake) - inhibit cardiac and vascular remodeling (associated with HTN, HF, MI)	- vasodilation (reduces arterial pressure, preload, afterload) - ↓ blood volume (promotes Na and H_2O excretion, blocking AngII in kidney stimulation of aldosterone secretion) - depress sympathetic activity (blocking AngII effects on sympathetic nerve release, and NE reuptake) - inhibit cardiac and vascular remodeling (associated with HTN, HF, MI)
Side Effects:	- hyperkalemia - dry cough, angioedema (due to ↑ bradykinin) - hypotension (orthostatic; especially HF patients) - AKI/kidney failure; ARB/aliskiren use; fluid depleted patient [contraindicated: pregnancy]	- hyperkalemia - dry cough, not as common; can also cause palpitations - hypotension (orthostatic; especially HF patients) - AKI/kidney failure; ARB/aliskiren use [contraindicated: pregnancy]
Indication:	- HTN (long-term BP lowering effect) - HF (cardioprotective) - Post-MI - renal protective; CKD, DM with albuminuria	- HTN - HF (cardioprotective) - Post-MI - renal protective; CKD, DM with albuminuria
Therapeutics:	- monitor in combination with aldosterone antagonists - careful with salt substances - do not use NSAIDs chronically - less effective in African Americans	- compared to ACEI: less dry cough, less angioedema - least frequency of side effects - do not use NSAIDs chronically - somewhat expensive
Monitor:	- BP - serum electrolytes (higher SCr ↓kidney fn; watch high K) - cough/angioedema - urinary proteins	- BP - serum electrolytes (higher SCr ↓kidney fn; watch high K) - cough/angioedema - urinary proteins

Diuretics	Loop	Thiazide	K-Sparing
Drugs	furosemide, bumetanide, torsemide, ethacrynic acid	hydrochlorothiazide, chlorothiazide chlorthalidone, indapamide, metolazone	aldosterone antagonist – spironolactone, eplerenone Na channel inhibitors – triamterene, amiloride
MoA:	- inhibit reabsorption of NaCl and KCl by inhibiting NaKCC2 cotransporter in TAL (more Na+H_2O excreted) - increase Ca and Mg excretion - increase renal blood flow due to increased renal prostaglandins (prostaglandins cause vasodilation)	- inhibit Na/Cl transporter in DCT; prevents Na reabsorption, thus Na excreted, and H_2O follows - decrease Ca excretion	- inhibit Na reabsorption
Location:	thick ascending limb (TAL) via luminal tubular secretion	distal convoluted tubule (DCT)	collecting duct
CV Effects:	- ↓ blood volume - ↓ cardiac output - ↓ venous pressure - ↓ systemic vascular resistance (long-term)	- ↓ blood volume - ↓ cardiac output - ↓ venous pressure - ↓ systemic vascular resistance (long-term)	- ↓ blood volume - ↓ cardiac output - ↓ venous pressure - ↓ systemic vascular resistance (long-term)
Side Effects:	- hypokalemia - ototoxicity - Mg depletion	- hypokalemia - muscle cramps/heart palpitations - hyperglycemia (minor); - hyperlipidemia: TG, TC, LDL-C (minor) - gout (if predisposed); hyperuricemia	- hyperkalemia (decreased Na reabsorption accompanied by decrease in K excretion in CD) - palpitations, kidney stones - avoid cyclosporine (hyperkalemia) - gynecomastia (spirono), hirsutism (spirono)
Indication:	- HF - HTN (usually with edema/HF) - anion overdose - acute renal failure	- HTN (most common diuretic) - HF (mild)	- HF (aldosterone antagonists also known as MRAs) - Serum K level (in combo with other diuretics) - resistant HTN (aa) - HTN with edema (combo Dyazide, Midamor)
Therapeutics:	- not for pregnancy or drug-induced edema (DHP) - careful in elderly/reduced renal function - sulfonamide allergy - preferred in extreme renal insufficiency (eGFR <30)	- qam dosing - best in combination; ceiling effect (5% Na block max) - photosensitivity (SPF 15) - less effective in renal insufficiency (eGFR <30mL/min) - well tolerated, inexpensive	- use in patients with lower K
Monitor:	- BP (specifically hypotension; dizziness) - kidney function (BUN, SCr) - uric acid (gout) - serum electrolytes (look for low K, low Mg, high Ca) - weight (due to initial diuresis, esp HF)	- BP (specifically hypotension; dizziness) - kidney function (BUN, SCr) - uric acid (gout) - serum electrolytes (look for low K, low Mg, high Ca) - weight (due to initial diuresis, esp HF)	- serum K (watch for high K >5.5) - renal function (<30)

Sympatholytic	α2-agonist (centrally-acting agonists)	α-blockers	β-blockers
Drugs	clonidine, methyldopa, guanfacine	α1 – doxazosin, prazosin, terazosin, alfuzosin α1 & α2 – phentolamine, phenoxybenzamine	β1 – acebutolol (P), atenolol, bisoprolol, metoprolol, esmolol β1/β2 – propranolol, nadolol, sotalol (K), pindolol (P), timolol β1/β2 α-activity – carvedilol, labetalol (vasodilation, NO release)
MoA:	- ↓ sympathetic outflow from CNS by activating α2-receptors in brain - increases binding of NE to α2 receptors, which negative feedback loop ↓NE: ↓HR, contractility, vascular tone (↓CO ↓SVR)	- block NE on post-syn α1 & α2 - post-syn (α1 & α2) on VSM: contraction - pre-syn (α2) on nerve terminals: ↓NE as feedback regulation	- block binding of NE/E to β-receptors; ↓ renin release (β1 & β2 nonselective; β1, cardioselective) - partial agonists (ace, pind) - membrane stabilizing effect
Location:	presynaptic α2 receptors at in brain	vascular smooth muscle (VSM)	- β1(heart)/β2(kidney, lungs) receptors on cardiac muscles (Gs); ↑cAMP, ↑PKA, ↑Ca = contraction - β2 receptors on VSM (Gs); ↑cAMP, ↓MLCK = relaxation
CV Effects:	- ↓ HR - ↓ contractility - ↓ vascular tone	- vasodilation – block post-synaptic α1 & α2 - ↑HR ↑contractility (side effect) – block pre-synaptic α2 which leads to ↑NE, then pre-syn α2-receptor ↓NE, via feedback mechanism; due to activating β-receptors in heart - ↓TPR/SVR ↓BP	- ↓HR - ↓contractility - ↓conduction velocity - mild vasoconstriction (β2); note: cardiac >> vascular effect - decrease SVR with long-term use (↓renin)
Side Effects:	- sedation, depression, dry mouth - fluid retention (if long term, use with diuretics) - rebound HTN if stopped suddenly (taper, then replace with other antihypertensives) - bradycardia (increased vagal stimulation); orthostatic HTN; constipation, nausea, GI effects	- orthostatic HTN (dizziness) - reflex tachycardia (especially nonselective) - fluid retention (most effective with diuretics and β-blockers), edema - nasal congestion and headache	- hypotension, bradycardia (dizziness, fatigue), AV block; contra SA/AV node disease w/o pacemaker - bronchoconstriction (β2-receptors, nonselective drugs); contra bronchospasms - change lipid profile (↑TGs, ↓HDL-C) - used cautiously in DM, tachy masked for hypoglycemia - withdrawal symptoms; don't stop abruptly
Indication:	- HTN (moderate, when others don't work) - effective in HTN with renal disease (don't compromise renal function)	- α1: primary HTN; BPH - α1 & α2: HTN emergency caused by pheochromocytoma (adrenal tumor excessive NE)	- HTN (more effective when ↑ sympathetic activity) - MI and angina (first-line stable angina) - arrhythmias - HF (only metoprolol succinate, bisoprolol, carvedilol)
Therapeutics:	- do not stop abruptly; - patch option - not in CHF - methyldopa can use in pregnancy	- "first dose" effect/orthostatic HTN - use with diuretics and β-blockers	- cardioselective (β1): metoprolol, atenolol, bisoprolol - nonselective (β1/β2): propranolol, nadolol (LA) intrinsic sympathomimetic activity: acebutolol (β1, partial agonism can lead to vasodilation effects), pindolol (β1/β2) - blocking α-receptors (β1/β2): carvedilol, labetalol - modify therapy QT prolonging; careful asthma or DM - CYP2C19 2D6 3A4 substrates (inhibitors and inducers)
Monitor:			- pulse (goal 50-60bpm) since BP not significant; ECG - rebound hypertension